

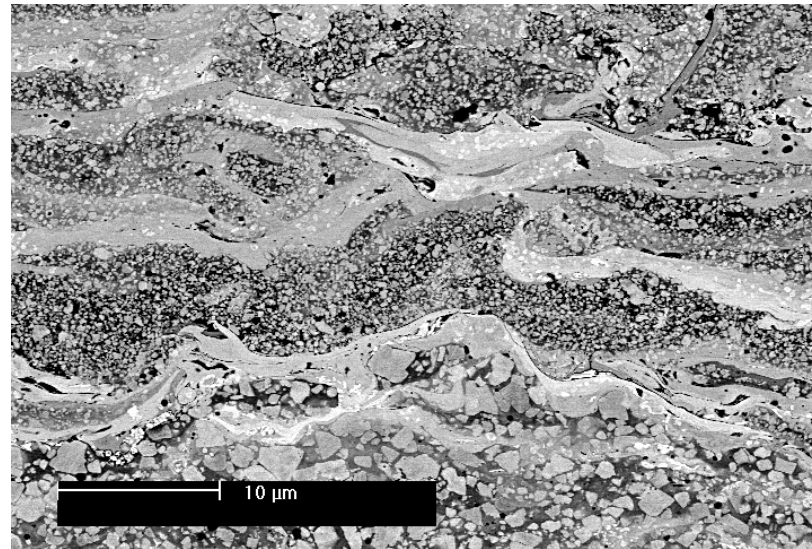
Thermal Sprayed Nanostructured Coatings

Lawrence Kabacoff
Office of Naval Research
kabacol@onr.navy.mil

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Thermal Sprayed Coatings

- Thermal spray inevitably forms layered structures
- Properties dominated by "splat boundaries"
- Mechanical Bond
- Evaluation can be a very complex business
- Process control limited (for now)





Formation of Nanoscale Microstructure in Coating

- Agglomerates experience significant heating in plasma
- Ways of obtaining nanoscale microstructure:
 - Avoid melting or grain growth (very difficult!)
 - Inclusion of phase or particles with high T_m
 - Formation of new nanoscale microstructure during solidification
 - Two or more immiscible phases present
 - Formation of single metastable phase during quenching (in the case of $\text{Al}_2\text{O}_3\text{-TiO}_2$, this is highly defected spinel)
 - Decomposition into nanocomposite



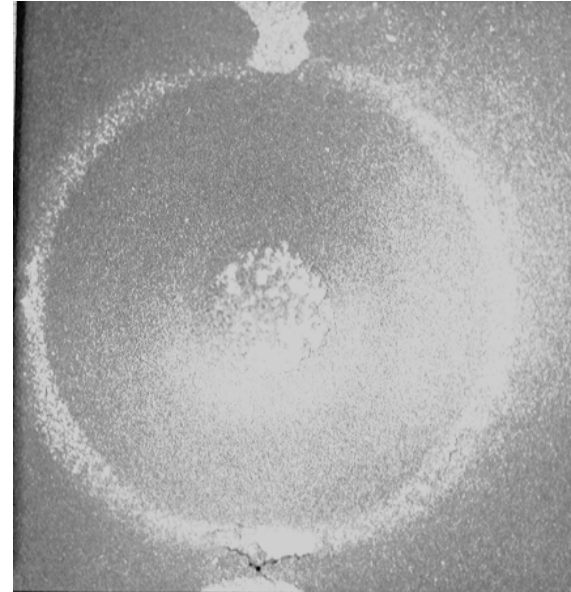
Ceramic Coatings

- Feedstock
 - Conventional: fused and crushed
 - “Nano”: Spray dried agglomerates of nanoparticles
- Properties
 - Distinctly different microstructures
 - “Nano” better only within specific range of spray parameters
 - For optimum parameters, “nano” distinctly “better”
 - Higher bond strength and wear resistance
 - Remarkable strain tolerance and “toughness”

Strain Tolerance: Cup Test

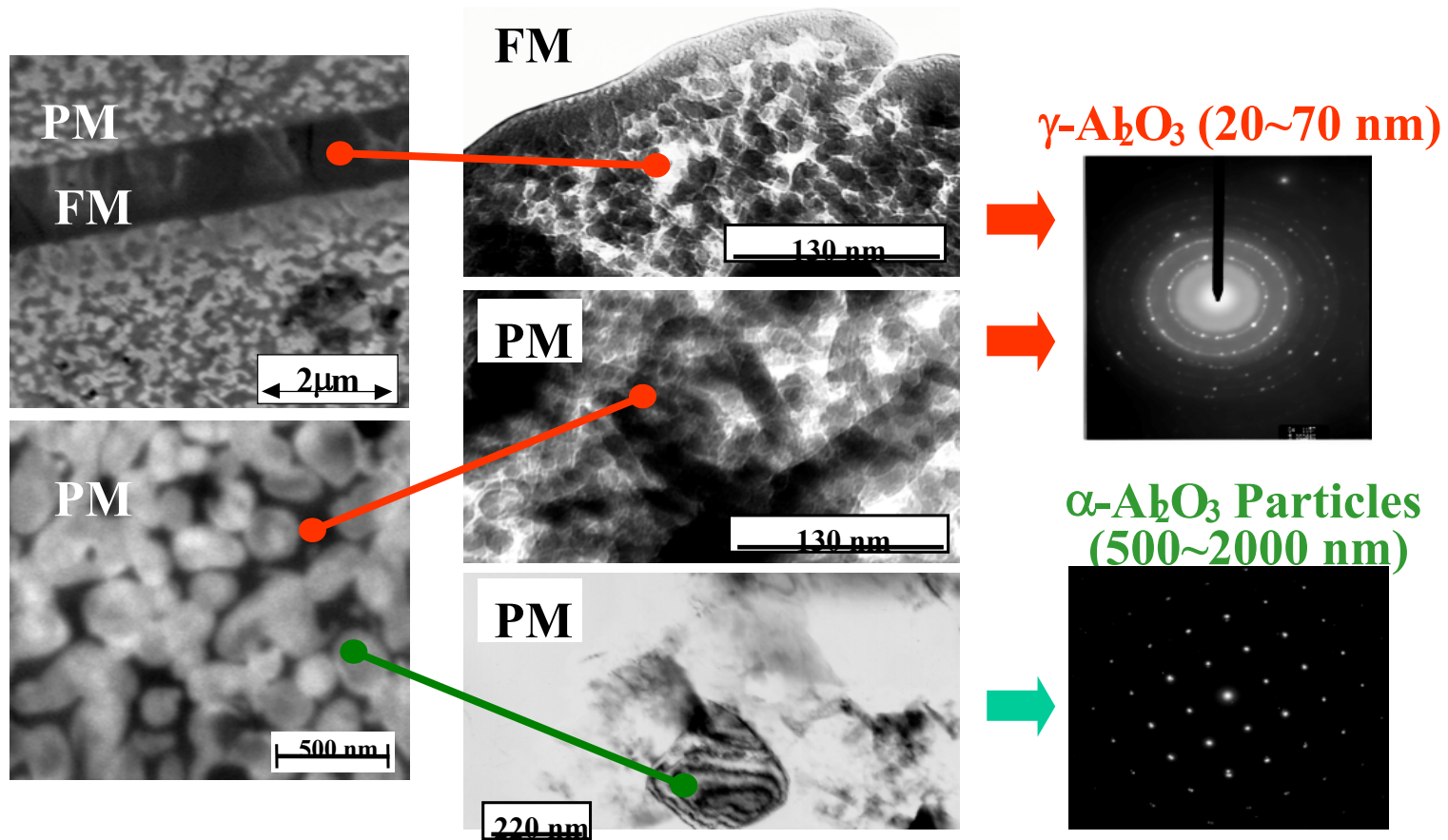


**CONVENTIONALLY
GRAINED ALUMINA
TITANIA**

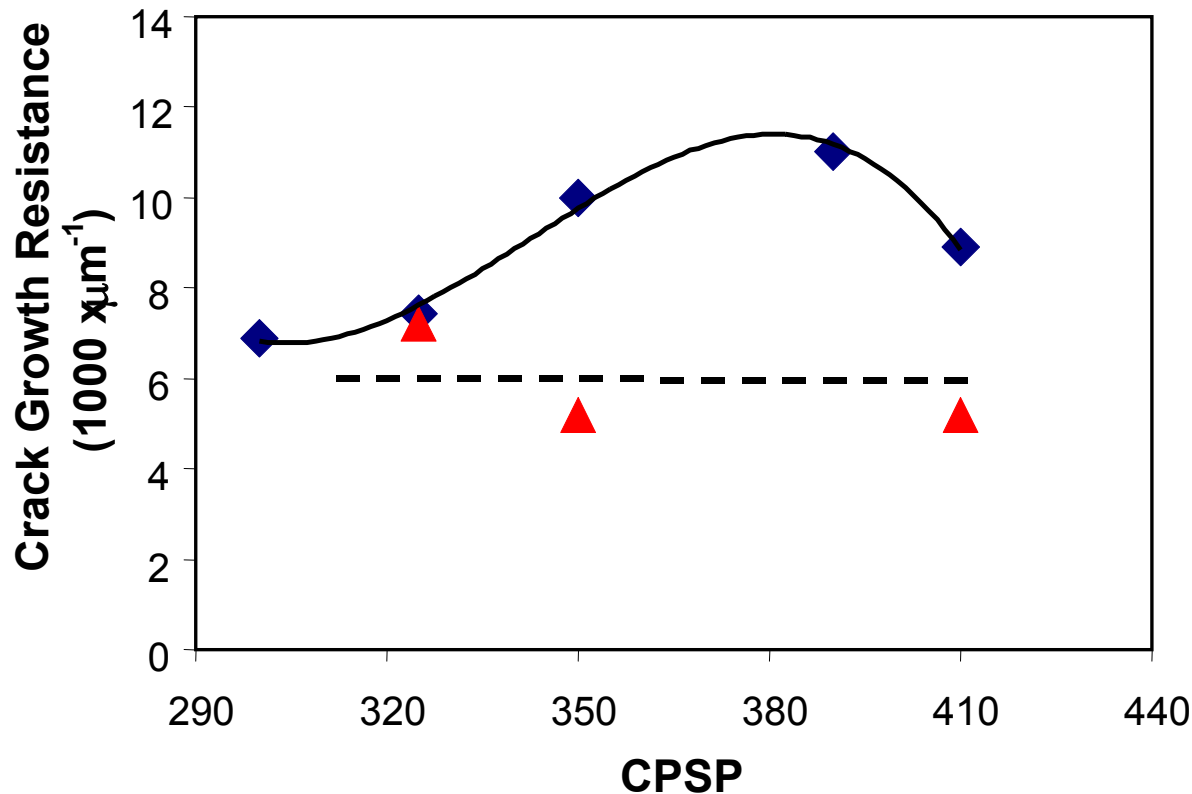


**NANOSTRUCTURE
GRAINED ALUMINA
TITANIA**

Microstructure of Nanostructured Alumina-Titania Coatings

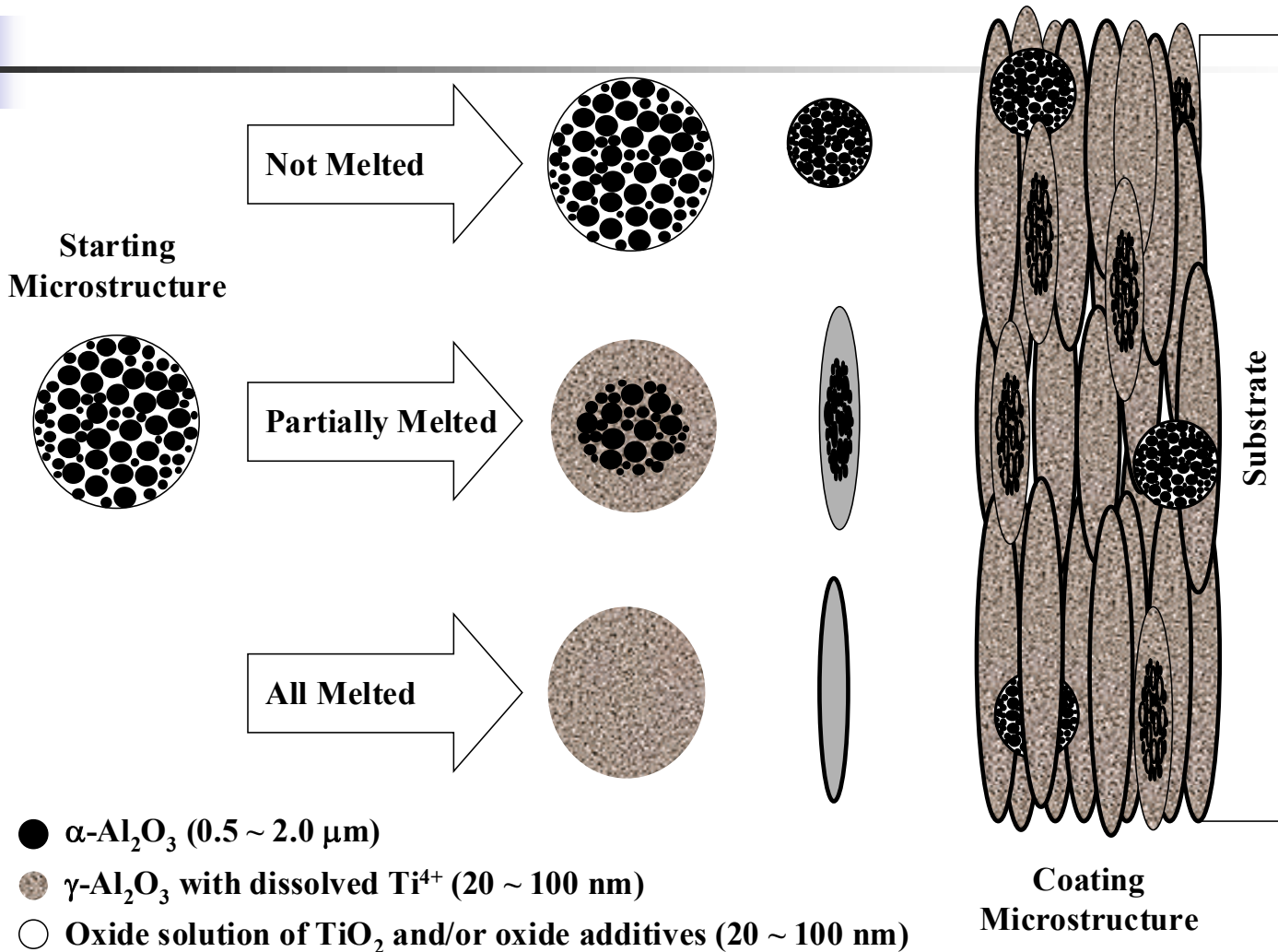


Comparison of Indentation Crack Growth Resistance

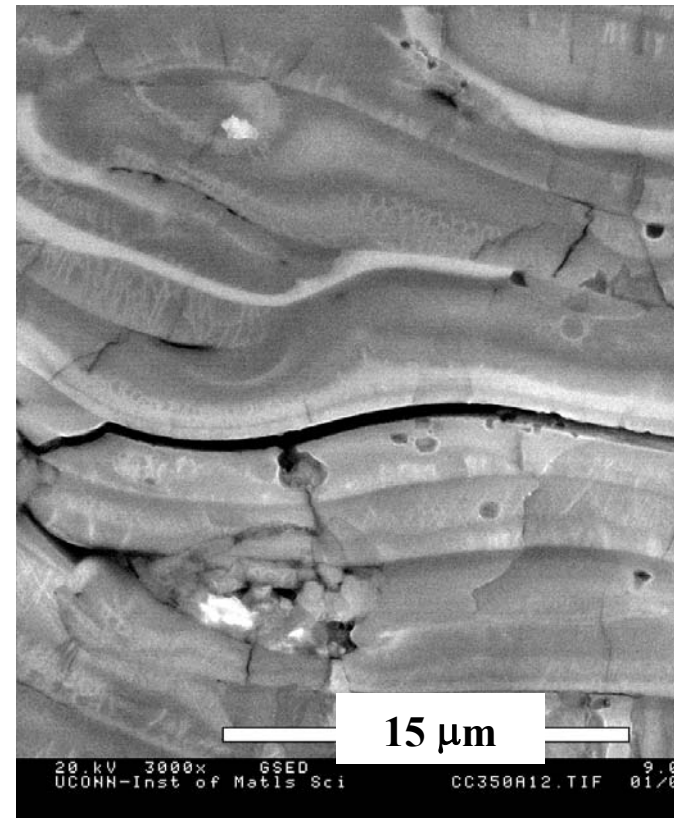
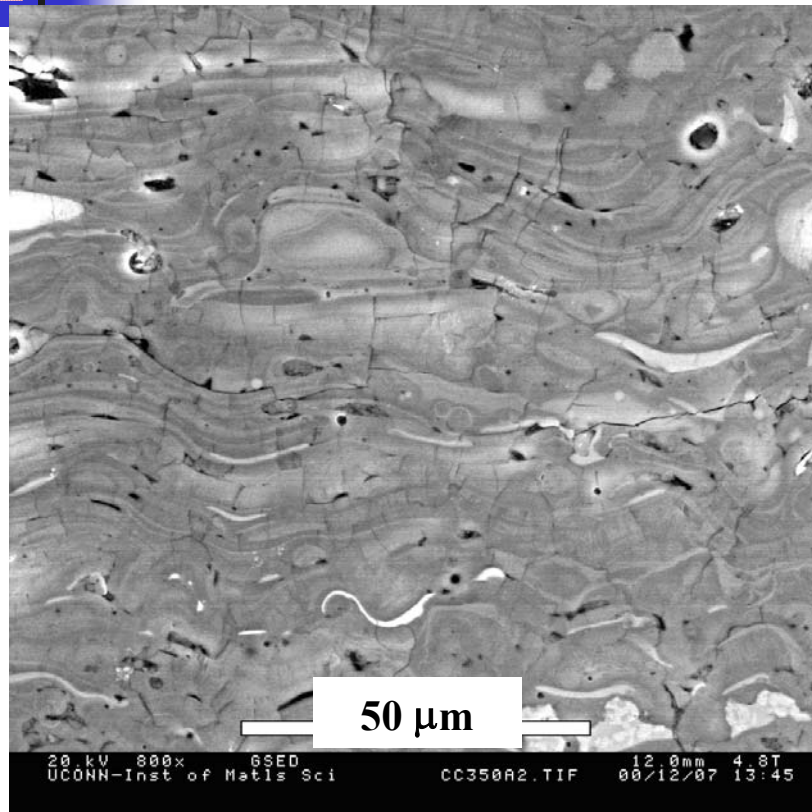


Courtesy of M. Gell and E. Jordan, UCONN

Microstructural Development of Nanostructured Alumina-Titania Coatings

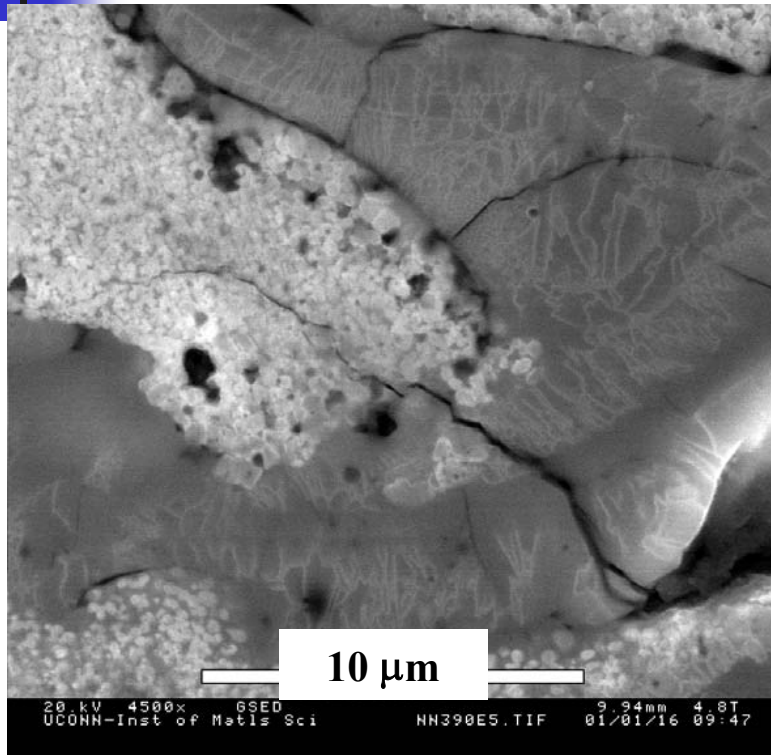


Interactions between Cracks and Microstructure (Metco 130)

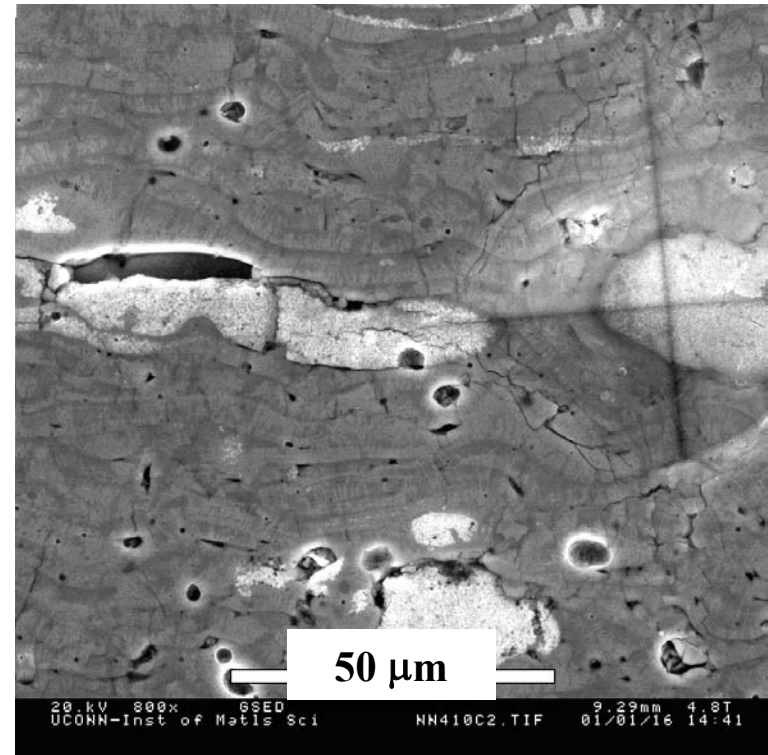


Most of the cracks propagate along splat boundaries!

Interactions between Cracks and Microstructure (NN Series)



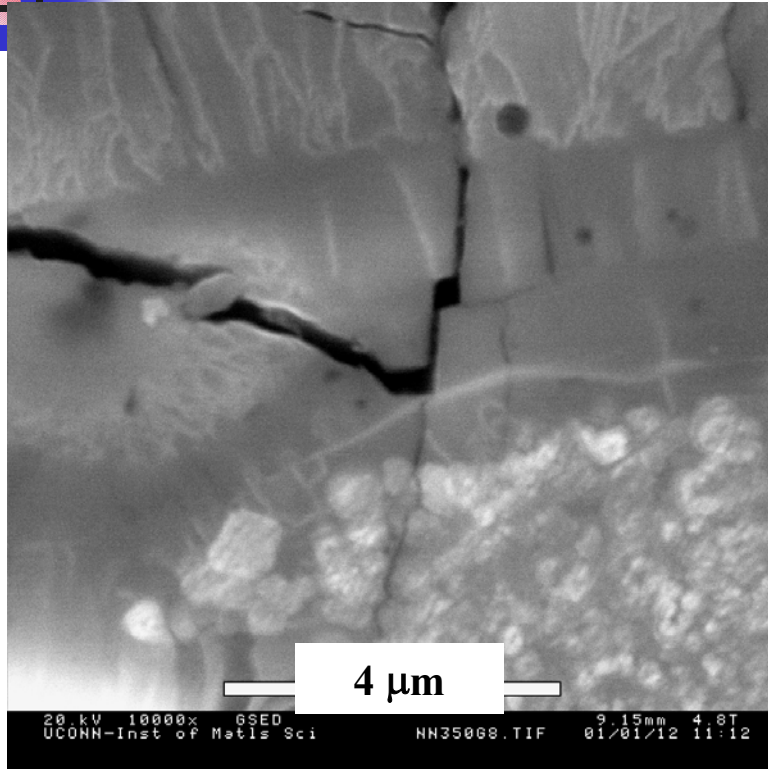
NN 390



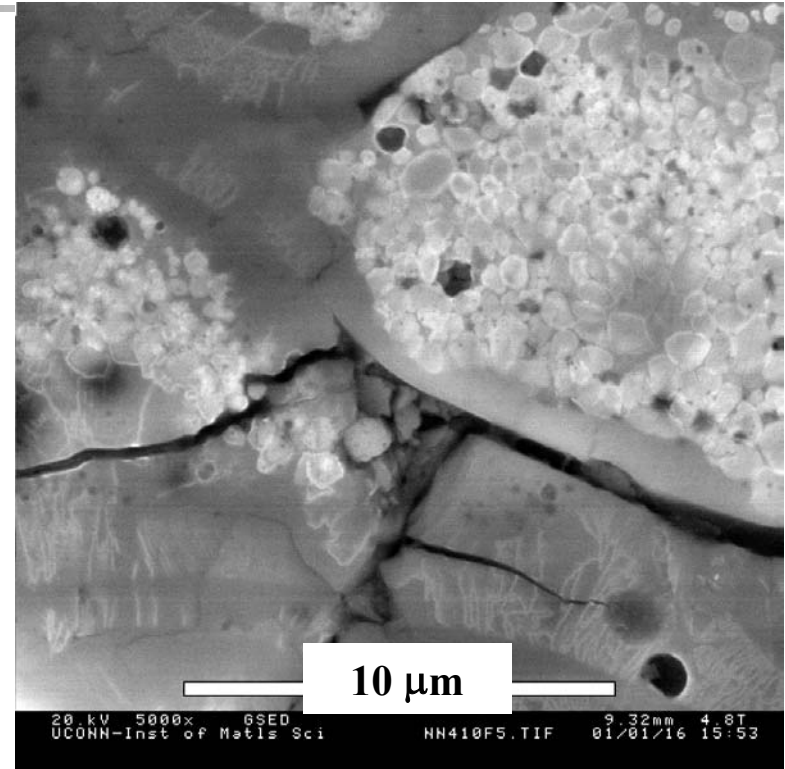
NN 410

Cracks are trapped in partially melted regions!

Interactions between Cracks and Microstructure (NN Series)



NN 390



NN 410

Cracks are deflected by partially melted regions!

Applications: Examples

- Main propulsion shafting for Mine Countermeasures (MCM) ships
- Through-hull submarine ball valves
- Gear shafts (80 Ton air conditioning units for surface ships)





Cermets

- Maintaining nanostructure “easy” because carbides do not melt
- n -WC-Co difficult to spray
 - *High surface area*
 - *Decarburization*
 - *Dissolution*
 - *Very temperature and porosity sensitive*
- *Large carbide particles best for abrasive wear resistance*
 - *“Nano” is for toughness and bond strength*
 - *“Bi-modal” structure may be best*

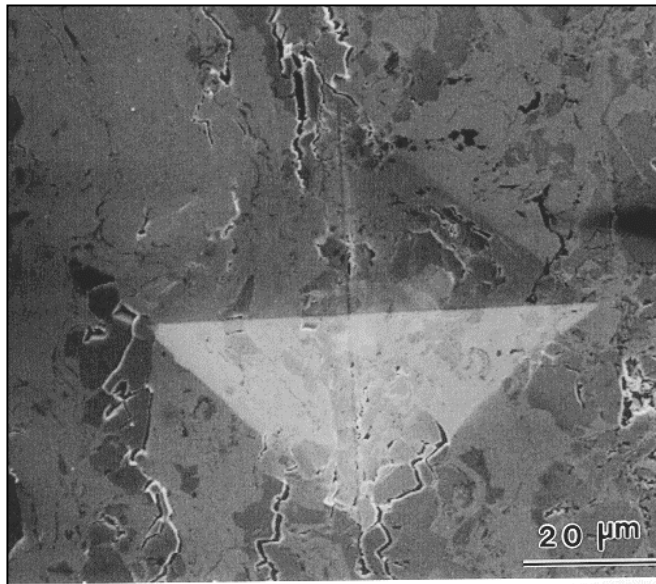


Status of *n*-Cermet Coatings

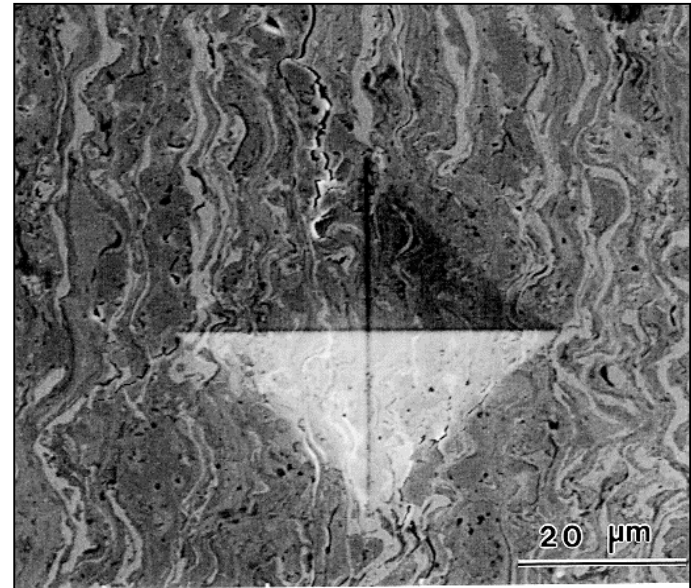
- NiCr-CrC much less sensitive to decarburization
 - Attritor milling of powder for feedstock
 - “Nano” coatings both harder and tougher
- Re-processing of WC-Co powder
 - Densify spray particles
 - New processes for producing *n*-WC-Co
- Mix nano and coarse carbides in 30/70 ratio
- National Research Council of Canada continuing development through consortium

Attritor Milled NiCr-CrC

Conventional



Nanostructured



$\text{Cr}_3\text{C}_2/\text{NiCr}$ Coatings
1000 g load